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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 268
Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. ▼ July 20, 1915.

CROP PRODUCTION IN THE GREAT PLAINS AREA

RELATION OF CULTURAL METHODS TO YIELDS

By

E. C. CHILCOTT, Agriculturist in Charge, and J. S. COLE
and W. W. BURR, Assistants, Office of
Dry-Land Agriculture

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INTRODUCTION.

This bulletin presents a summary of data obtained relative to the effect of cultural methods upon crop production in the Great Plains area. Six department bulletins have recently been published by the Office of Dry-Land Agriculture, dealing largely with this subject. In these are treated separately the effect of cultural methods upon the production of spring wheat, of oats, of corn, of barley, and of corn, milo, and kafir, and one deals with the effects of the time of plowing. The experimental results are presented in these bulletins in much greater detail than is possible in the present bulletin, and the reader is referred to them for the details of these investigations.[1]

The investigations upon which these conclusions are based were conducted at 14 field stations, located at Moccasin and Huntley, Mont.; Williston, Dickinson, Hettinger, and Edgeley, N. Dak.; Belle Fourche, S. Dak.; North Platte and Scottsbluff, Nebr.; Akron, Colo.; Hays and Garden City, Kans.; and Amarillo and Dalhart, Tex.

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[1] See bulletins of the United States Department of Agriculture bearing numbers and titles as follows: No. 214, "Spring wheat in the Great Plains area: Relation of cultural methods to production." No. 218, "Oats in the Great Plains area: Relation of cultural methods to production." No. 219, "Corn in the Great Plains area: Relation of cultural methods to production." No. 222, "Barley in the Great Plains area: Relation of cultural methods to production." No. 242, "Corn, milo, and kafir in the southern Great Plains area: Relation of cultural methods to production." No. 253, "The effect of different times of plowing small-grain stubble in eastern Colorado."

Note.—This bulletin is intended for all who are interested in the agricultural possibilities of the Great Plains area.

The Great Plains area to which the conclusions in this bulletin apply is shown by the map (fig. 1). The dots show the locations of the 14 field stations mentioned. The eastern boundary of the area is the ninety-eighth meridian and the western boundary is the 5,000-foot contour along the eastern foothills of the Rocky Mountains. The altitude along the eastern boundary ranges from approximately 1,000 feet in the southeastern portion to 1,400 in the northeastern. The average altitude of the southern portion is higher than that of the northern. The length of the area from north to south is about 1,000 miles and the width from east to west about 400 miles. The area contains, therefore, about 400,000 square miles.

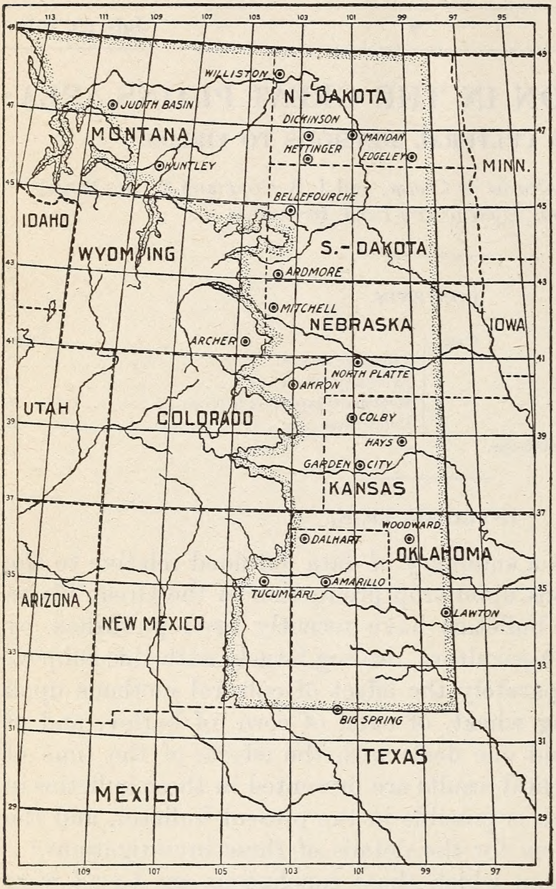

FIG. 1.—Sketch map of the Great Plains area, which includes parts of ten States and consists of about 400,000 square miles of territory. Its western boundary is indicated by the 5,000-foot contour. The location of each field station within the area is shown by a dot within a circle (⊙).

The period of time covered by the investigations at the several stations ranges from two to eight years. The aggregate of the years at all these stations is 80. The average number of the separate plats used each year is 1,900. The number of moisture determinations made at all the stations during the entire period is approximately 91,000.

The work has been conducted in cooperation with the State agricultural experiment stations in Montana, North Dakota, Nebraska, and Kansas, and with the Biophysical Laboratory, the Office of Western Irrigation Agriculture, and the Office of Cereal Investigations of the Bureau of Plant Industry. The entire scientific staff of the Office of Dry-Land Agriculture, numbering about 30 men, has participated in the details of the field work and the preparation of the data for publication. The investigations have also had the benefit of the counsel and advice of the scientists connected with the various cooperating offices and State agricultural experiment stations.

CLIMATIC FEATURES OF THE GREAT PLAINS.

The climate of the Great Plains has been classified as semiarid. It may be better to say that it is variable. One season may have almost humid and another almost arid conditions. The mean annual precipitation is relatively low. Years of relatively high precipitation may be followed by years of relatively low precipitation. Other climatic factors usually correspond with the rainfall. In a year of relatively high rainfall there will be a lower rate of evaporation and higher humidity than in a year of low rainfall.

Another climatic factor of much importance in crop production on the Plains is the distribution of the rainfall. This is probably more important in crop production than the amount of annual rainfall. A relatively low rainfall, properly distributed, may produce a crop where a much higher rainfall, unfavorably distributed, may accompany a crop failure.

TABLE I.—*Annual and seasonal precipitation and seasonal evaporation at fourteen stations in the Great Plains area.*[1]

Station.	Altitude (feet)[2].	Precipitation (inches)[3].						Seasonal evaporation.[3]		
		Annual.			Seasonal.					
		Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.
Judith Basin	4,228	14.96	23.78	18.06	7.04	17.21	9.34	22.012	29.353	24.491
Huntley	3,000	11.92	11.92	11.92	5.92	6.02	5.97	23.754	24.214	23.984
Williston	1,875	10.28	18.99	14.84	4.75	14.49	9.66	20.422	26.877	24.216
Dickinson	2,543	11.93	21.22	16.69	6.85	16.28	9.79	20.673	25.745	23.919
Edgeley	1,468	11.94	21.95	16.71	7.85	14.98	10.11	18.663	24.893	21.866
Hettinger	2,253	12.72	15.68	14.20	8.92	12.47	10.36	21.539	28.239	24.639
Belle Fourche	2,950	6.64	17.73	13.11	4.08	9.78	6.90	26.472	33.750	28.794
Scottsbluff	3,950	13.77	18.51	16.14	2.53	8.52	4.69	23.804	29.381	26.081
North Platte	3,000	11.18	23.01	18.05	6.85	12.66	9.45	28.445	38.168	32.359
Akron	4,600	14.51	22.46	18.28	6.42	13.86	9.02	26.064	35.654	31.420
Hays	2,050	15.59	27.80	21.30	8.18	17.97	11.17	30.625	44.373	35.790
Garden City	2,900	11.82	23.58	18.54	2.79	14.43	8.65	34.325	43.510	38.185
Dalhart	4,000	13.69	16.35	15.11	5.09	9.85	8.01	35.459	41.748	38.988
Amarillo	3,676	10.69	27.80	18.28	6.17	11.38	9.13	33.804	42.076	36.724

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[1] The years covered are the same as for the data shown in the tables for the several stations.

[2] The altitude given is for the field where the work was done and is based in most cases on that of the nearest town.

[3] The records of annual precipitation for 1914 are not included. The records of seasonal precipitation and evaporation for 1914 are included for all stations, being figured from May 1 to Sept. 1. Evaporation measurements are made from a free water surface, in a tank sunk into the soil to almost its full depth. The water surface is kept about level with the surface of the ground.

Table I gives the maximum, minimum, and average annual precipitation and the seasonal maximum, minimum, and average precipitation and evaporation of the Great Plains area. By seasonal is meant the period between the average time of seeding and the average time of harvest.

Seasonal variations in climatic factors have been found in these investigations to be more important in determining crop production than have differences in methods of tillage. This is shown by the fact that at some stations in some years climatic conditions have been such that all methods have resulted in practical failures of the crops. In other years all methods have given fair returns.

Figure 2 shows the earliest and latest dates of the last killing frost in the spring, the earliest and latest dates of the first killing frost in the fall, and the average length of the frost-free period at each station. Each hatched horizontal bar represents the period between the average dates of the last killing frost in the spring and the first killing frost in the fall. The number of days in the average frost-free period for the station is shown in the figures above the bar. The solid-line curve at the left shows the earliest date at which the frost-free period has begun. The broken-line curve at the left represents the latest date at which the last killing frost of the spring has occurred. The solid-line curve at the right represents the earliest date and the broken-line curve at the right the latest date at which the first killing frost of the fall has occurred.

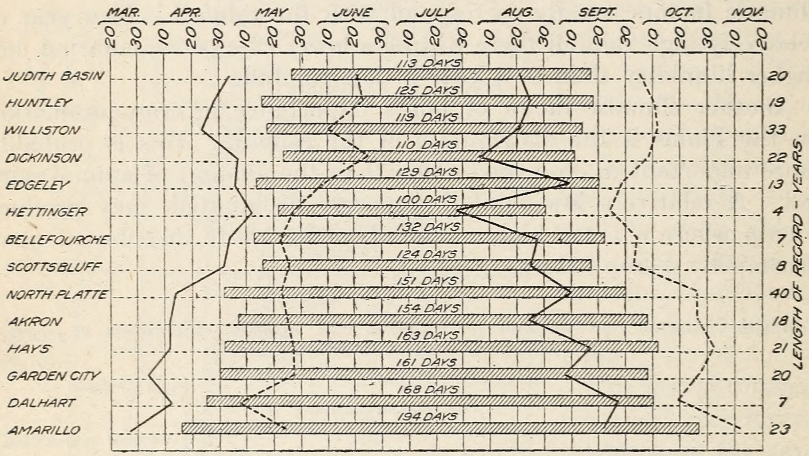

FIG. 2.—Diagram showing the average frost-free periods and the earliest and the latest dates at which the last killing frost in the spring and the first killing frost in the fall has occurred at fourteen stations in the Great Plains area.

This diagram shows clearly the increase in the length of the frost-free period from the north to the south. The shortest average period is 100 days, at Hettinger, and the longest 194 days, at Amarillo. The length of the period free from frost is more important in the production of corn than in the production of small grain. Young corn being easily injured by frost, planting must be delayed until there is little further danger from this source. Where the season is short, the crop may be caught by frost in the fall. This necessitates the use of short-season varieties in a portion of the Great Plains area.

SOILS OF THE GREAT PLAINS.

As would naturally be expected in so extensive an area, the soils of the Great Plains present a great diversity; but as it is only that portion of the area which is adapted to dry farming with which these studies deal, all of the alluvial bottoms, the sand hills, the "bad lands," and the rough, broken, and mountainous portions are eliminated. This elimination greatly reduces the diversity of soil types to be considered. The 14 field stations already mentioned were located with a view to having each of them on soil representative of extensive areas. It is believed, therefore, that the soils of these stations represent nearly all of the important soil types to be found in the strictly dry-farming portions of the Great Plains. The conclusions drawn from experiments conducted at these 14 stations, therefore, should apply to the Great Plains area as a whole, and those from individual stations, or from groups of stations, to extensive subdivisions of the area.

Space here will not permit of a detailed discussion of the soils at each station. Brief descriptions of the soils at these stations are given in a bulletin recently published.[1]

CROPS AND CULTURAL METHODS.

The principal crops under investigation are spring wheat, winter wheat, oats, barley, corn, milo, and kafir. The methods of soil preparation include fall plowing, spring plowing, disking corn stubble, subsoiling, green manuring, and summer tillage, and listing for small grain, corn, milo, and kafir. Detailed descriptions of these various methods are given in the publications cited on page 1.

RESULTS OF METHODS TESTED WITH VARIOUS CROPS.

In this bulletin a table will be presented for each of the crops considered, the results for milo and kafir being combined in one table. The first part of each table shows the average yields obtained at each station by each method under trial. It also shows the number of years and total number of plats used in obtaining the average. In the case of the small grains only, the method of seed-bed preparation is considered, without reference to the previous crop. In the tables for corn, milo, and kafir, the tables show the effect of the previous crop, as well as the effect of the method. Under the headings, "Fall plowed," "Spring plowed," and "Green manured" in the tables for the small grains are shown the average yields obtained from ground so prepared following several different crops, usually wheat, oats, barley, or corn. The disked land has been chiefly corn land. Listing and subsoiling have been done on land continuously devoted to the crop for which results are presented. The second part of the table shows the comparative profit or loss resulting from growing each crop by the various methods under study. The profits and losses are based on the average yields shown in the first part of the table.

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[1] Bulletin U. S. Dept. of Agriculture No. 214, entitled "Spring Wheat in the Great Plains area: Relation of cultural methods to production," 43 p., 1915.

The method of computing the cost of production and of valuing the crop has been shown in detail in the publication previously cited.[1] The cost is based on a land rental of $1.60 per acre and an average wage of $2 per day for a man and $1 per day for a horse. With this wage as a basis, the labor cost is computed on the average amount of work required by each method under trial. The cost of production as computed is not offered as being absolute for any locality, either in amount or cost of labor required, but is given as a working basis for the comparison of the results from different methods of preparation.

SPRING WHEAT.

The results with spring wheat are summarized in Table II. In the first part of the table are brought together for each station the average yields as grouped for this study under different methods of preparation. In the second part of the table the profit or loss in dollars and cents per acre for the average crop for each method is shown. This digest is based on the yield data presented in the first part of the same table.

When fall plowing following corn, oats, and wheat is averaged together and compared with spring plowing following the same crops, the average yields from each of the two methods at 11 of the 14 stations show no material difference for the years averaged. At only three stations—Scottsbluff, Akron, and Hays—are the average differences greater than 1 bushel per acre. At Hays the advantage is with fall plowing and at the other two stations with spring plowing. At most stations the advantage of one method over the other depends chiefly upon the season. The effect of different times of plowing small grain stubble has been treated in detail in a separate publication. The small difference in the cost of the two methods makes relative profits and losses from them follow closely the differences in yields.

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[1] U. S. Dept. of Agriculture Bulletin No. 214, entitled "Spring Wheat in the Great Plains area: Relation of cultural methods to production," 1915, p. 8–11.

TABLE II.—*Average yields and digest of cost of production per acre of spring wheat by different methods of tillage at fourteen stations in the Great Plains area.*

Points covered.	Fall plowed.		Spring plowed.		Disked.		Listed.		Subsoiled.		Green. Manured.		Summer tilled.		Number of years averaged.
	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	
Yields (bushels):															
Judith Basin	25	22.1	24	21.7	40	22.5	5	21.7	5	22.8	10	20.4	19	20.8	5
Huntley	8	20.0	6	19.5	16	22.4	2	18.0	2	16.0	4	22.3	6	25.9	2
Williston	20	15.3	15	15.9	35	16.2	....	......	....	......	10	18.6	15	20.2	5
Dickinson	30	20.1	18	19.8	54	23.3	....	......	....	......	30	22.2	18	27.5	6
Edgeley	32	15.3	30	15.5	86	17.7	....	......	....	......	23	16.7	37	17.9	8
Hettinger	15	13.4	9	13.7	36	15.7	....	......	....	......	12	14.6	24	20.4	3
Belle Fourche	24	7.0	18	6.5	72	8.8	6	7.5	6	6.7	24	9.2	30	11.5	6
Scottsbluff	15	9.6	12	11.5	33	14.0	3	9.4	3	9.4	6	13.3	9	19.9	3
North Platte	40	11.6	32	10.6	67	10.5	....	......	....	......	....	......	24	16.8	8
Akron	34	9.4	20	12.3	24	11.2	6	8.6	6	7.4	18	9.9	12	14.6	6
Hays	25	6.6	15	4.8	5	7.0	5	6.7	5	6.4	....	......	10	8.0	5
Garden City	30	4.1	14	3.1	10	4.6	5	5.1	5	4.2	8	3.7	15	6.0	5
Dalhart	20	2.2	16	1.9	12	1.8	4	5.4	....	......	8	0.3	8	5.8	4
Amarillo	27	6.2	21	6.1	6	6.6	6	7.4	6	8.1	12	8.6	18	12.6	6
Cost of production	$6.56		$6.09		$4.75		$5.55		$7.17		$14.61		$11.50		....
Profit or loss (−):															
Judith Basin	8.91		9.10		11.00		9.64		8.79		− 0.33		3.06		5
Huntley	7.44		7.56		10.93		7.05		4.03		1.00		6.63		2
Williston	4.15		5.04		6.59		....		....		− 1.59		2.64		5
Dickinson	7.51		7.77		11.56		....		....		.93		7.75		6
Edgeley	4.15		4.76		7.64		....		....		− 2.92		1.03		8
Hettinger	2.82		3.55		6.24		....		....		− 4.39		2.78		3
Belle Fourche	−1.66		−1.54		1.41		− .30		−2.48		− 7.17		−3.45		6
Scottsbluff	.16		1.56		5.05		1.03		− .59		− 5.30		2.43		3
North Platte	1.56		1.33		2.53		....		....		....		.26		8
Akron	.02		2.52		3.09		.47		−1.99		− 7.68		−1.28		6
Hays	−1.94		−2.73		.15		− .86		−2.69		....		−5.90		5
Garden City	−3.69		−3.90		−1.53		−1.98		−4.23		−12.02		−7.30		4
Dalhart	−5.51		−5.23		−3.91		−3.03		....		−14.47		−8.77		6
Amarillo	−2.22		−1.82		− .13		− .37		−1.50		− 8.59		−2.68		6

Wheat on disked corn ground has given consistently high yields. This, together with the low cost of this preparation for wheat, has resulted in its uniformly showing the greatest profit per acre at those stations where wheat has been produced at a profit and the least loss at those stations where wheat has been produced at a loss by all methods. The only exception to this is at Dalhart, where yields have been so low as to be of little practical moment. The realization of these profits depends, of course, upon the profitable production of corn, in competition with other crops, as a general farm crop.

It should be borne in mind that at all stations disking corn ground as a preparation for all small-grain crops has been done on corn land kept free from weeds. If weeds were allowed to develop in the corn, similar results should not be expected. To the extent that the weeds developed or were unhindered in their growth would the corn ground approach a grain stubble in the condition of the seed bed. If they matured seed, further damage might be done by their growth in the succeeding crop.

Subsoiling, as compared with fall plowing similar wheat stubble without subsoiling, has been of doubtful utility as a means of increasing yields. As a means of overcoming drought it is without value. At Judith Basin and Scottsbluff it has shown a small increase in yield over a comparable plat fall plowed without subsoiling, but the increase was hardly sufficient to pay the extra labor costs. The evidence from eight stations, some of which have eight years' records, indicates that working the soil to a greater depth than is reached by the ordinary plow is not essential. This indication is strengthened by data from other work not yet published on deep plowing and dynamiting.

Listing wheat stubble instead of plowing it in the fall has resulted in a small increase in yield at seven of the eight stations where it has been tried. At Amarillo it has increased the yields in the years of heaviest wheat production. At the same station it shows a slight loss in the average for all years when compared with a comparable plat fall plowed. As it is a somewhat cheaper method of preparation than fall plowing it has been a more profitable one.

Except at Judith Basin and Akron, wheat after summer tillage has given the highest average yields at each station of any method under trial. At Akron the yield of wheat on summer-tilled land has been exceeded by that on spring-plowed corn ground by 0.3 of a bushel per acre. The average of spring plowing is, however, below the average of summer tillage. The reason for the departure at Judith Basin is doubtless that of the depth and type of soil at that station. For the whole 14 stations under study the average increase in yield over disked corn ground has been 3.1 bushels per acre. Summer tillage requires the use of the land for two years to produce a crop and requires an extra amount of cultivation to keep it free from weeds in the fallow year. It consequently has the highest acre cost of any method under trial except its modification—green manuring. A study of the relative profits and losses from different methods, as given in Table II, shows that the increase in cost of production by summer tillage has been relatively greater than the increase in yields resultant from it. It has not at any station been the most profitable when a profit was realized, nor has it been the source of the least loss where wheat has been raised at a loss. At six stations it shows a profit, but a smaller one than was realized from some other method or methods. At four other stations it has resulted in a loss, while some other methods have resulted in profit. At the remaining four stations its practice has increased the loss attending the use of less expensive methods.

Green manuring is the most expensive method under trial. It resembles a fallow in that it requires the use of the land two years to produce one crop, but it has the added expense of seed and seeding.

There is a saving in cultivation during the spring while the green-manure crop is growing, but this is partially offset by the necessity of a second plowing to turn this crop under and is not sufficient to make up for the cost of seed and seeding. The yields have not been commensurate with the increase in the cost of producing them. At no station have the average yields following any green manure exceeded those from summer-tilled land. At all stations except Huntley and Dickinson the result has been a monetary loss, both actually and in comparison with other methods. These are the two stations that have had the highest average yields.

It is hardly fair to charge the whole expense of green manuring to the one crop that immediately follows it, as is here done, as it should have a cumulative effect in building up the soil or remedying its deficiency in organic matter. The available evidence is that on normal soils in the Great Plains area, at least in the first years of the work, little effect is shown on any other than the first crop. This effect is like that of a fallow, in that water is stored during the period after the crop is plowed under.

WINTER WHEAT.

Cultural methods for winter wheat have been under trial at all stations except those in North Dakota. No varieties at present available have sufficient hardiness to survive the winters in that State. In the rest of the Great Plains winter wheat is more successful. In dry falls there is trouble in getting germination and a good stand with some methods. At some of the stations there is more or less trouble with winterkilling. When winter wheat fails to start in the fall or to survive the winter it can often be successfully replaced with spring-sown varieties. When it survives the winter, it is quite generally more productive than spring wheat. At those stations where it is adapted it makes a greater response to cultural methods, particularly to summer tillage, than does spring wheat. Table III presents the average yields and the average profit or loss from each cultural method at each of the stations at which the crop has been under trial.

At Garden City, Dalhart, and Amarillo there have been so many failures and such poor yields when a crop was produced that the averages are very low. At these three stations the only material difference in the results from different methods has been a small increase in yields on summer-tilled land at Amarillo. This increase in the crop has not been proportionally as great, however, as the increase in the cost of production by the use of this method. The only profit from winter wheat by any method at these three stations has been 8 cents per acre on disked corn ground at Amarillo.

At the Judith Basin and Huntley stations the season is so short that it is not possible to make much difference in the time of plowing for winter wheat. The difference has been in depth of plowing rather than in time of plowing, the plat under the heading "Late fall plowed" having been plowed shallower than the one headed "Early fall plowed." At Huntley the results seem to have favored shallow plowing. The chief thing to be noted in the results from these stations is the general lack of difference in the yields from methods other than summer tillage. At the Judith Basin station summer tillage has increased the yields from five to six bushels per acre. The increase has not been sufficient to pay for the increased cost of production by this method. Huntley has only two years' record. During these years the average yield of winter wheat on summer-tilled land has been over 40 bushels per acre as compared with yields of about 30 bushels from other methods. This makes both the yield and the profit from winter wheat after summer tillage at this station greater than by any other method at any station.

TABLE III.—*Average yields and digest of cost of production per acre of winter wheat by different methods of tillage at ten stations in the Great Plains area.*

Points covered.	Early fall plowed.		Late fall plowed.		Disked.		Listed.		Subsoiled.		Green manured.		Summer tilled.		Number of years averaged.
	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	
Yields (bushels):															
Judith Basin	5	19.8	5	20.2	4	22.5	5	19.8	5	20.0	2	23.5	8	25.7	5
Huntley	1	25.7	1	30.8	8	29.5	1	26.2	1	27.8	8	32.4	6	41.1	2
Belle Fourche	6	11.6	6	8.4	....	....	6	9.7	6	10.5	....	....	6	18.4	6
Scottsbluff	3	10.6	3	6.4	9	14.8	....	....	....	....	6	15.3	6	19.9	3
North Platte	....	10.6	....	....	....	....	....	....	....	....	....	....	....	30.8	3
Akron	5	14.1	5	13.3	15	19.2	5	14.7	5	11.8	40	16.7	10	21.8	5
Hays	7	15.8	7	11.6	28	12.4	7	19.4	7	19.1	34	14.2	13	21.7	7
Garden City	7	1.1	7	1.2	14	1.5	13	1.5	7	1.1	53	2.6	7	2.8	7
Dalhart	4	2.5	4	3.0	9	0	4	2.5	....	....	24	0	7	3.3	4
Amarillo	6	8.2	6	7.2	12	6.9	6	6.4	6	6.9	36	7.7	12	10.7	6
Cost of production	$6.56		$5.85		$4.75		$5.55		$7.17		$14.61		$11.50		....
Profit or loss (—):															
Judith Basin	7.30		8.29		....		8.31		6.83		....		6.49		5
Huntley	11.43		15.71		15.90		12.79		12.29		8.07		17.27		2
Belle Fourche	1.56		.03		....		1.24		.18		....		1.38		6
Scottsbluff	.86		— .63		5.67		....		....		— 3.90		2.43		3
North Platte	.86		....		....		....		....		....		10.06		8
Akron	3.31		3.46		10.69		4.74		1.09		— 2.92		3.76		5
Hays	4.50		2.27		3.93		8.03		6.20		— 4.67		3.69		7
Garden City	—5.79		—5.01		—3.70		—4.50		—6.40		—12.79		—9.54		6
Dalhart	—4.81		—3.75		....		—3.80		....		....		—9.19		4
Amarillo	— .82		— .81		.08		—1.07		—2.34		— 9.22		—4.01		6

At North Platte, data for a sufficient number of years to be of value are available for only two methods, early fall plowing of land continuously cropped to winter wheat and summer tillage. The average yield from summer tillage has been 30.8 bushels and from continuous cropping only 10.6 bushels per acre. At Belle Fourche, Scottsbluff, Akron, and Hays, early fall plowing has increased the yields over late fall plowing. A still greater increase has been obtained by growing the crop on summer-tilled land. The increase in yield at all of these stations except Hays has been sufficient to justify the use of this method for winter wheat if the results are to be compared with those from wheat stubble plowed in the fall.

At Akron the greatest profit has been realized from the growth of the crop on disked corn ground. At Hays land treated with the lister after harvest and land subsoiled have given decidedly the greatest profits.

The yields following the plowing under of rye or peas for green manure have approached, but in no case equaled, those on summer-tilled land. The greater cost of the method removes it from competition with other methods.

OATS.

In Table IV are brought together for the several stations the average yields of oats and the cost of production data as grouped for study under different methods of preparation, showing the profit or loss per acre for the average crop for each method for which it has been computed at each station.

Table IV.—*Average yields and digest of cost of production per acre of oats by different methods of tillage at fourteen stations in the Great Plains area.*

Points covered.	Fall plowed.		Spring plowed.		Disked.		Listed.		Subsoiled.		Green manured.		Summer tilled.		Number of years averaged.
	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	
Yields (bushels):															
Judith Basin	42	49.9	20	51.2	28	53.3	5	49.9	5	49.5	20	54.8	15	58.4	5
Huntley	12	43.4	8	49.2	16	53.0	2	47.2	2	46.1	8	58.6	6	59.2	2
Williston	30	33.5	20	36.2	20	37.9	....	......	....	......	10	39.1	15	43.9	5
Dickinson	36	34.4	42	36.9	30	47.5	....	......	....	......	18	44.0	18	49.9	6
Edgeley	51	32.2	39	31.4	49	33.5	....	......	....	......	21	35.1	34	38.3	8
Hettinger	18	22.8	21	32.0	21	35.1	....	......	....	......	9	22.2	15	32.1	3
Belle Fourche	36	16.1	24	18.0	48	21.9	6	18.8	6	17.5	24	22.4	30	29.8	6
Scottsbluff	21	18.2	18	22.2	24	26.3	3	20.4	3	20.4	15	28.7	12	38.2	3
North Platte	48	17.8	48	18.5	8	17.9	....	......	....	......	31	22.0	32	27.4	8
Akron	30	21.7	24	23.9	72	20.5	6	21.9	6	16.9	18	19.9	18	28.7	6
Hays	30	20.7	24	17.6	12	20.7	6	22.9	6	22.7	....	......	12	24.8	6
Garden City	25	8.7	20	6.0	65	8.8	5	12.8	5	9.2	10	9.2	15	12.8	5
Dalhart	16	4.5	12	3.5	44	4.0	4	5.9	....	......	8	.3	12	9.3	4
Amarillo	30	17.6	24	15.1	60	15.8	6	17.0	6	15.1	12	17.3	12	27.6	6
Cost of production	$6.31		$5.84		$4.50		$5.30		$6.92		$14.36		$11.25		....
Profit or loss (−):															
Judith Basin	8.66		9.52		11.49		9.67		7.93		2.08		6.27		5
Huntley	6.71		8.92		11.40		8.86		6.91		3.22		6.51		2
Williston	3.74		5.02		6.87		....		....		−2.63		1.92		5
Dickinson	4.01		5.23		9.75		....		....		−1.16		3.72		6
Edgeley	3.35		3.58		5.55		....		....		−3.83		.24		8
Hettinger	.53		3.76		6.03		....		....		−7.70		−1.62		3
Belle Fourche	−1.48		− .44		2.07		.34		−1.67		−7.64		−2.31		6
Scottsbluff	− .85		.82		3.39		.82		− .80		−5.75		.21		3
North Platte	− .97		− .29		.87		....		....		−7.76		−3.03		8
Akron	.20		1.33		1.65		1.27		−1.85		−8.39		−2.64		6
Hays	− .10		− .56		1.71		1.57		− .11		....		−3.81		6
Garden City	−3.70		−4.04		−1.86		−1.46		−4.16		−11.60		−7.41		5
Dalhart	−4.96		−4.79		−3.30		−3.53		....		−14.27		−8.46		6
Amarillo	−1.03		−1.31		.24		− .20		−2.39		− 9.17		−2.97		6

Perhaps the first thing that impresses one in viewing the average yields from all stations is the much greater adaptation of oats to the northern than to the southern section of the Plains. There is an almost constant decrease in yields from the northern, cooler, shorter season stations to the southern, warmer, longer season ones. This decrease is about the same for the heavier yielding as it is for the lighter yielding methods. This decrease in yield from north to south for all methods proves that the problem is one of adaptation of crops to conditions rather than one that can be overcome by cultural practices.

General averages for all of the stations mean little, as differences in yield obtained at one station by the combination of factors that determine yield may be balanced by differences in an opposite direction, as a result of a different combination of factors, at another station. With the trifling exception of a fraction of a bushel at Edgeley, spring plowing at all stations north of Hays has given higher average yields than fall plowing. At Hays and the stations south of it, fall plowing has been in about an equal degree better than spring plowing. The greater number of stations represented in the northern group makes the general average of averages show a small margin in favor of spring plowing. The general average, however, is of little value. It should not influence the practice at those stations whose results show fall plowing to be for them the best practice.

At all of the stations north of North Platte, disking has been productive of higher average yields than either fall or spring plowing. At North Platte, Dalhart, and Amarillo, it has been between the two in yield. At Hays it has yielded the same as fall plowing and higher than spring plowing. At Garden City it has yielded higher than either. In the general average of all the stations reported it has given a yield of 28.3 bushels per acre against 25.8 bushels for spring plowing and 24.4 bushels for fall plowing. The great bulk of the land disked is corn ground.

With the exception of a sharp decrease from subsoiling at Akron and a similar increase from listing at Garden City, the yields from each of these practices have not departed far from the yields of ordinary plowing.

Green-manured land has been productive of higher yields than either fall or spring plowed or disked corn ground at 9 of the 13 stations from which results from it are reported. At Dickinson it has given lower yields than disked corn ground. At Hettinger, Akron, and Dalhart it has yielded less than any of the three methods mentioned. At Amarillo fall-plowed land has exceeded it in yield.

Summer tillage has produced higher yields than any of the methods under trial at every station except Hettinger, where it has been exceeded only by disking corn ground. Averaged for all the stations, its increase of yield over fall plowing has lacked one-tenth of a bushel of being 10 bushels per acre. The greatest departure from this general average is at Scottsbluff, where the increase has amounted to 20 bushels per acre.

As values and cost of production are here figured, it is seen in Table IV that oats have been produced at a profit by at least one method at all stations except Garden City and Dalhart. At two stations, Judith Basin and Huntley, a profit has been realized from all methods.

Comparatively good yields, combined with low cost of production, have usually made disked land, which has been chiefly corn ground, show the greatest profit at all stations where a profit has been realized from any method.

At all stations where it has been tried, listing has either been more profitable or has resulted in less loss than fall plowing.

Subsoiling has yielded a profit at two stations and a loss at six. It could not, however, be said that it was a profitable practice at any station, as the profits from it have been less and the losses from it greater than from fall plowing. It should be compared with fall plowing, as it is a modification of that method.

At all the 10 stations north of Hays, except Belle Fourche and North Platte, where the losses per acre have been $0.44 and $0.29, respectively, spring plowing has been productive of profitable crops. At Hays the average loss from it is only $0.56 per acre. At Amarillo the loss has increased to $1.31. At Garden City and Dalhart there was a loss, but all methods resulted in a loss at these stations.

At Akron and all North Dakota and Montana stations, fall plowing shows a profit. At Scottsbluff the nominal profits from spring plowing have been converted to nominal losses by fall plowing. At the other stations the losses from the two methods are about the same.

The cost of green manuring has been so high that at only two stations, Judith Basin and Huntley, has it shown a profit. At those stations the profits were smaller than those from any other method. At all other stations it has either converted the profit of other methods into a loss, or has been productive of the greatest loss. In probably only two or three cases has the loss been small enough to make it possible to change it to a profit by distributing a part of the cost to following crops.

Summer tillage as here figured shows a profit at six stations and a loss at eight. In two cases the profits are nominal—i. e., they are so small that changes in the average yields by extension of the record might change their position. In no case has the profit as here figured been as great as from some other method. Except at Dalhart and Garden City the losses at the eight stations showing a loss have averaged from $1.62 to $3.81. Considering the fact that summer tillage sometimes produces a crop when other methods fail, it seems that it might have a place in the production of oats, even though somewhat greater net profits may be obtained in the average of a series of years by other methods. Surety of production, especially of feed crops, is as important, if not more important, than the amount of net profits per acre.

BARLEY.

In Table V are brought together for the several stations the average yields of barley from different methods of preparation. The profit or loss per acre for the average crop for each method for which it has been computed is also shown.

TABLE V.—*Average yields and digest of cost of production per acre of barley by different methods of tillage at fourteen stations in the Great Plains area.*

Points covered.	Fall plowed.		Spring plowed.		Disked.		Listed.		Subsoiled.		Green manured.		Summer tilled.		Number of years averaged.
	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	Number of plats.	Average yield.	
Yields (bushels):															
Judith Basin	5	24.0	9	24.0	5	29.0	5	29.0	5	30.5	...	...	5	30.2	5
Huntley	...	...	2	29.6	8	34.5	...	...	...	...	4	43.8	...	...	2
Williston	5	17.4	10	16.1	5	27.5	...	...	...	...	...	...	5	28.8	5
Dickinson	6	25.1	12	24.6	6	37.4	...	...	...	...	...	...	6	32.5	6
Edgeley	8	16.7	16	18.5	8	23.4	...	...	...	...	...	...	8	20.0	8
Hettinger	3	19.9	6	25.5	3	14.9	...	...	...	...	...	...	3	31.8	3
Belle Fourche	6	7.6	12	8.3	6	12.2	6	7.7	6	8.0	...	...	6	12.6	6
Scottsbluff	2	14.0	4	15.4	2	18.6	2	14.4	2	15.0	...	...	2	27.6	2
North Platte	8	17.1	16	15.9	8	13.4	...	...	...	...	...	...	8	26.7	8
Akron	6	18.6	12	18.8	18	18.4	6	17.9	6	14.0	...	...	6	24.8	6
Hays	6	13.6	12	11.2	36	14.1	6	12.7	6	14.6	12	15.5	6	19.3	6
Garden City	5	6.9	10	4.3	15	8.9	5	8.3	5	6.9	...	...	5	11.0	5
Dalhart	4	3.9	8	1.9	12	1.6	4	4.4	...	...	...	...	4	6.4	4
Amarillo	6	8.2	12	5.7	6	6.6	6	6.1	6	6.8	...	...	6	12.6	6
Cost of production	$6.46		$5.99		$4.65		$5.45		$7.07		$14.51		$11.40		2
Profit or loss (−):															
Judith Basin	3.38		3.85		7.24		6.44		5.44		...		.98		5
Huntley	...		6.15		9.50		...		...		3.45		...		3
Williston	.67		.61		6.63		...		...		...		.41		5
Dickinson	3.83		4.10		10.68		...		...		...		1.93		6
Edgeley	.39		1.60		4.94		...		...		...		−3.20		8
Hettinger	1.70		4.47		1.46		...		...		...		1.64		3
Belle Fourche	−3.34		−2.59		.35		−2.29		−3.79		...		−6.23		6
Scottsbluff	− .72		.32		2.98		.45		− .92		...		− .08		2
North Platte	.55		.53		.84		...		...		...		− .45		8
Akron	1.17		1.72		2.89		1.89		−1.33		...		−1.23		6
Hays	− .88		−1.40		1.13		− .24		−1.08		−8.15		−3.49		6
Garden City	−3.63		−4.23		−1.00		−2.05		−4.24		...		−6.89		5
Dalhart	−4.86		−5.21		−3.99		−3.65		...		...		−8.78		4
Amarillo	−3.10		−3.65		−1.94		−2.95		−4.28		...		−6.23		6

It is conspicuous in Table V that the yields at Belle Fourche, Garden City, Dalhart, and Amarillo have been markedly lower than at the 10 other stations. While some methods have increased the yields at these stations, they have not brought them up to a point that offers much encouragement for the growth of this crop. The only profit shown at these stations from any method under study is one of 35 cents per acre from disking corn ground at Belle Fourche. This nominal profit has resulted from the low cost of production rather than from the amount of yield. The indications are that the combination of soil and climatic conditions at these stations is not congenial to the growth of barley, nor can the unfavorable conditions be overcome by cultural methods.

Table V also shows that at 10 of the 14 stations under study, disked corn ground has been productive of higher yields of barley than either fall or spring plowed stubble. At Hettinger and North Platte it has been clearly exceeded in yield by each. At Akron it has been exceeded in yield by both, but the differences between the three are only fractions of a bushel. At Amarillo it has been between the two in yield. Its low cost of production has made disking the most profitable method under trial at all stations except Hettinger. It has been productive of a profit at all stations except Garden City, Dalhart, and Amarillo.

Preparing the ground with a lister instead of a plow has been practiced at eight stations. At only one station, Judith Basin, have the yields been very materially different from those by fall plowing. At the other stations, although it has not in all cases given higher yields than plowing, owing to a lower cost of preparation, it has shown slightly more profit where profits are shown and less loss where losses are shown than has resulted from plowing.

The difference between spring and fall plowing is largely one of season. In the average of the 13 stations at which both were under trial, there is practically no difference. At only three stations is there a difference of over 2 bushels per acre in the yields from the two methods. At the four southern stations the advantage has been with fall plowing. This is the only consistent territorial difference to be noted in the comparison of these two methods, but production at these four stations and at Belle Fourche has been at a loss by both methods. Spring plowing shows a profit at all other stations and fall plowing at all others except Scottsbluff.

Subsoiling in preparation for the barley crop has been practiced at seven stations. At only two of these has the consequent yield departed far from that by fall plowing. At the Judith Basin station there has been a marked gain and at Akron a marked decrease from subsoiling. The cost of the method has been such that it has paid a profit at only the Judith Basin station.

The highest average yields at 11 of the 14 stations have been from summer-tilled land. At the Judith Basin station subsoiled land has yielded a fraction of a bushel higher. At Dickinson and Edgeley the yields on disked corn ground have been appreciably higher than on summer-tilled land. While the averages of all the stations are not strictly comparable, summer tillage has increased the yield over fall and spring plowing of cropped land nearly one-half. The average increase over disking corn ground has not been nearly so great.

These increases in yields have not been in proportion to the increased cost of the method. In no case has it been the most profitable method under trial. As values and cost are here figured, this method shows a profit at only four stations, Judith Basin, Williston, Dickinson, and Hettinger. At Scottsbluff, North Platte, and Hays the losses have been small. At the other seven stations they have been sufficiently great to discourage the hope of changing them to profits by the extension of the record or by the adjustment of value or cost.

Green manuring for barley has been tried at only two stations, Huntley and Hays. At Huntley, where it was in comparison with only spring plowing and disking corn ground, it gave the highest yield. This average is the highest resulting from any method at any station. The record, however, is for only two years. At Hays the yield from this preparation has been higher than that on land from which a crop was harvested, but not as high as on summer-tilled land.

CORN.

In Table VI are assembled the average yields of corn produced by each method at the several stations. The profits or losses attending the use of each method in the production of corn are also shown.

Table VI shows that during the years covered by this work creditable average yields of grain have been obtained from all methods at Huntley, Williston, Dickinson, Scottsbluff, North Platte, and Akron, and from one method at Belle Fourche and Dalhart. No grain has been produced at either the Judith Basin station or at Garden City.

The corn is harvested either when mature or when growth is stopped by frost. It is cut with a binder and shocked in the field. The shocks stand until cured, usually about a month. They are then weighed, and the sound corn, if any, is husked and weighed. Where sound corn is produced, the yield as tabulated is given in bushels as "Grain." The term "Stover"[1] is used to show the total weight when no grain is produced and the difference between the weight of the grain and the total weight when corn is husked. The grain weights are converted into bushels on the basis of 70 to 75 pounds per bushel, depending upon the dryness at the time of husking.

There has been little difference in the average yields from the different cultural methods in use at Williston, Edgeley, Hays, and Amarillo. At Dickinson, Belle Fourche, and Dalhart, the only method of preparation giving yields departing far from the others has been summer tillage. At Dickinson this method has been responsible for a decrease and at Belle Fourche and Dalhart for an increase in yields.

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[1] In the tables of this bulletin only the term "stover" is used because the corn was husked whenever marketable or whenever it was produced in sufficient quantity to warrant husking. In cases where the yield of grain was not sufficient to warrant husking, the term "fodder" would be more exact.

TABLE VI.—*Average yields and digest of cost of production per acre of corn by different methods of tillage at thirteen stations in the Great Plains area.*

Points covered.		Fall plowed after—		Spring plowed after—		Subsoiled after corn.	Listed after corn.	Summer tilled.	Number of years averaged.
		Corn.	Small grain.	Corn.	Small grain.				
Yields per acre:									
Judith Basin	Number of plats	5	45	5	80	5	10	5	5
	Grain...bushels	0	0	0	0	0	0	0	
	Stover..pounds	5,744	5,275	6,002	5,193	6,130	5,982	5,656	
Huntley	Number of plats	2	12	2	32	2	2	2	2
	Grain...bushels	14.0	19.4	21.8	25.2	19.8	26.3	26.1	
	Stover..pounds	1,380	1,497	1,375	1,654	1,945	1,605	1,695	
Williston	Number of plats	5	20	5	60	....	....	5	5
	Grain...bushels	15.3	12.8	15.1	14.1	....	....	17.6	
	Stover..pounds	5,542	1,743	5,780	6,537	....	....	5,924	
Dickinson	Number of plats	6	24	6	96	....	....	6	6
	Grain...bushels	19.9	20.6	21.5	19.8	....	....	14.5	
	Stover..pounds	2,105	2,144	2,362	2,408	....	....	1,822	
Edgeley	Number of plats	8	40	8	160	....	....	8	8
	Grain...bushels	7.0	8.2	7.3	8.4	....	....	6.8	
	Stover..pounds	3,039	3,201	3,129	3,245	....	....	2,926	
Belle Fourche	Number of plats	6	24	6	102	6	6	6	6
	Grain...bushels	10.0	8.1	9.8	7.8	9.4	10.3	17.0	
	Stover..pounds	2,288	1,655	2,145	1,724	2,125	2,129	2,178	
Scottsbluff	Number of plats	3	27	3	60	3	3	3	3
	Grain..bushels	30.1	24.5	27.9	27.5	26.8	24.9	39.0	
	Stover..pounds	1,753	2,516	1,913	2,770	2,280	1,740	3,200	
North Platte	Number of plats	8	72	8	72	....	....	8	8
	Grain...bushels	18.2	13.3	18.5	13.2	....	....	20.8	
	Stover..pounds	2,383	2,143	2,438	2,307	....	....	2,711	
Akron	Number of plats	6	72	6	54	6	12	6	6
	Grain...bushels	20.0	12.9	19.4	13.7	16.8	13.9	20.9	
	Stover..pounds	2,292	1,769	2,388	1,746	2,113	1,962	2,257	
Hays	Number of plats	6	24	6	60	6	6	6	6
	Grain...bushels	6.2	5.5	6.1	6.9	8.3	6.2	9.9	
	Stover..pounds	3,226	3,512	3,668	3,290	3,486	3,093	3,929	
Garden City	Number of plats	5	55	5	55	5	10	5	5
	Grain...bushels	0	0	0	0	0	0	0	
	Stover..pounds	3,020	2,768	3,047	2,688	3,363	2,819	4,700	
Dalhart	Number of plats	6	72	6	42	....	6	6	6
	Grain...bushels	8.6	7.3	9.5	7.0	....	14.0	13.7	
	Stover..pounds	2,711	2,569	2,725	2,280	....	2,588	3,900	
Amarillo	Number of plats	7	77	7	21	7	14	7	7
	Grain...bushels	5.8	5.4	5.1	4.3	6.0	7.0	8.6	
	Stover..pounds	2,491	2,301	1,921	2,023	2,481	1,925	3,037	
Cost of production		$7.49	$7.49	$7.11	$7.11	$8.18	$5.98	$12.36	....
Profit or loss (—):									
Judith Basin		4.00	3.06	4.89	3.28	4.08	5.98	—1.05	5
Huntley		.87	3.26	4.36	6.28	3.63	7.75	1.47	2
Williston		9.71	11.92	10.49	11.60	....	....	6.53	5
Dickinson		4.67	5.04	6.21	5.63	....	....	—2.92	6
Edgeley		1.38	2.19	2.07	2.74	....	....	—3.79	8
Belle Fourche		1.09	— .94	1.10	— .51	— .17	2.40	—1.20	6
Scottsbluff		8.06	7.34	7.88	9.43	7.10	7.46	9.64	3
North Platte		4.56	2.12	5.17	2.78	....	....	1.38	8
Akron		5.09	1.21	5.43	1.86	2.77	3.50	.51	6
Hays		1.44	1.73	2.67	2.23	2.11	2.69	— .54	6
Garden City		—1.45	—1.95	—1.02	—1.73	—1.45	— .34	—2.96	5
Dalhart		1.37	.57	2.14	.25	....	4.80	.92	6
Amarillo		— .19	— .73	—1.23	—1.34	— .82	.67	—2.85	7

Between the yields following fall and spring plowing, there is little general difference to be noted except at Huntley and Scottsbluff. At Huntley spring plowing has been better than fall plowing. At Scottsbluff fall plowing has been better than spring plowing where corn follows corn and poorer than spring plowing where corn follows small grain.

At some stations more difference is to be noted as a result of crop sequence than as a result of difference in time of plowing. At Huntley corn has been better after small grain than after corn. At North Platte and Akron corn after corn on both fall-plowed and spring-plowed land has been markedly better than corn after small grain.

It appears that the yields of fodder reported from the Judith Basin Field Station and from Williston are abnormally high. While the yields have generally been good at these stations, it is doubtful whether they have been as much higher than those at some of the other stations as these figures indicate. It is probable that in the years showing excessively high yields the crop had not been well dried at the time of weighing.

A very striking fact brought out is the uniformity in the amount of stover or fodder produced by all methods at the stations in Montana and North Dakota. So far as the production of rough feed is concerned, there appears very little difference in the yields from the various methods on which to make a choice. South of North Dakota there is a general agreement of heavier yields of stover or fodder where corn follows corn than where corn follows small grain except at Scottsbluff, where the yields have been heavier after small grain than they have been after corn.

Small differences in stover yields are to be noted between the results following spring and fall plowing. On the whole, the average yields by the two methods are almost the same.

The most noticeable effect resulting from cultural practice is the very marked increase in the yields of stover resulting from growing corn on summer-tilled land at the more southern stations—Garden City, Dalhart, and Amarillo. Only small increases in yields attended this practice at Scottsbluff, North Platte, and Hays.

Subsoiling has not markedly affected the yields, except at Akron, where it has decreased them.

Listing has materially increased yields at Huntley and at Dalhart. At the other stations the effect has not been marked.

Table VI shows that corn is relatively much less profitable at Belle Fourche, Garden City, Dalhart, and Amarillo than at the other stations.

Scottsbluff is the only station where summer tillage as a preparation for corn has shown the most profit of all methods. At most of the stations this has been the least profitable method. It has resulted in actual loss at Judith Basin, Dickinson, Edgeley, Belle Fourche, Hays, Garden City, and Amarillo.

Another fact shown is the greater profit derived from the growth of corn after corn over corn after small grain at Akron and North Platte, and from corn following small grain over corn following corn at Huntley.

Listing has been tried at nine stations. Except at Scottsbluff and Akron it has been the most profitable method under trial. As has been pointed out, the relative profitableness of this method has been largely due to its low production cost rather than to increased yields.

A careful reading of the data given in Table VI will show that corn can not be profitably grown as a grain or cash crop in large portions of the Plains. At only 5 of the 13 stations have the grain yields been sufficiently large to indicate a possibility of the crop being profitably produced for the grain alone. At Huntley, Dickinson, Scottsbluff, North Platte, and Akron, enough grain has been produced by some methods to pay the cost of production and show small profits. Taken as a whole, however, the data show that in order to realize the full profit corn should be considered as a feed crop. To pay the cost of production, in many sections it is necessary to utilize the roughage produced. When this is done, the corn crop shows a profit at all stations except Garden City and Amarillo. It should therefore occupy a permanent place in the rotation except in the extreme southern portion of the area, as it leaves the soil in good condition for the crops that follow it.

MILO AND KAFIR.

The area to which milo and kafir are adapted has been shown in a previous publication.[1] Experimental work in methods of production of these crops has been done at Akron, Colo.; Hays and Garden City, Kans.; Dalhart and Amarillo, Tex.; and Tucumcari, N. Mex.

The latitude and altitude at Akron combine to make conditions generally unfavorable for either milo or kafir. In the production of grain they can not compete with corn. In the production of forage they can not compete with sweet sorghum.

At Hays both milo and kafir are of great value. The small area of the plats in the experimental work has subjected them to influences, such as ravages of insects, that are not generally experienced under field conditions. The data that have been obtained are not sufficient to permit adequate comparison either of results from different methods or of these crops with others.

At Tucumcari the work has not been carried on for a sufficient length of time to obtain averages that warrant the drawing of conclusions. Results from Akron, Hays, and Tucumcari are, therefore, not included in the tables.

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[1] Farmers' Bulletin 322, by Carleton R. Ball and Arthur H. Leidigh.

Table VII presents for milo and kafir the average results of growing these crops under various methods at Garden City, Dalhart, and Amarillo. The average yields of both grain and stover at these stations by each of the methods under study and also the profit or loss resulting from raising the crop are shown.

TABLE VII.—*Average yields and digest of cost of production per acre of milo and kafir by different methods of tillage at three stations in the Great Plains area.*[1]

Points covered.	Fall plowed.						Spring plowed, milo after milo, kafir after kafir.			Listed, milo after milo, kafir after kafir.			Summer tilled.		
	Milo after milo, kafir after kafir.			After small grain.											
	Number of plats.	Grain.	Stover.	Number of plats.	Grain.	Stover.	Number of plats.	Grain.	Stover.	Number of plats.	Grain.	Stover.	Number of plats.	Grain.	Stover.
Yields of milo:		*Bus.*	*Lbs.*		*Bus.*	*Lbs.*		*Bus.*	*Lbs.*		*Bus.*	*Lbs.*		*Bus.*	*Lbs.*
Garden City	6	8.8	2,152	10	10.5	2,556	6	6.2	1,873	6	8.8	2,036	.....	.....	.....
Dalhart	6	22.1	3,995	10	11.6	3,188	6	21.2	4,065	6	24.8	3,575	6	36.6	5,938
Amarillo	7	20.4	2,920	14	23.1	3,286	7	21.1	2,626	10	20.9	2,313	3	17.1	3,463
Yields of kafir:															
Garden City	6	6.6	3,262	10	6.9	4,229	6	4.7	2,910	6	4.5	2,943	.....	.....	.....
Dalhart	6	13.9	5,352	10	4.7	4,230	6	9.7	5,287	6	16.9	5,605	6	31.1	9,992
Amarillo	7	11.3	4,422	14	12.2	5,387	7	10.2	3,824	10	9.3	3,207	3	2.3	4,427
Cost of either crop	$7.44			$7.44			$7.06			$5.93			$12.31		
Profit or loss (−) on milo:															
Garden City	.38			2.07			−.83			1.59			......		
Dalhart	9.39			3.56			9.55			11.14			14.21		
Amarillo	6.56			8.37			6.63			7.06			1.46		
Profit or loss (−) on kafir:															
Garden City	1.72			3.78			.64			1.76			......		
Dalhart	8.82			2.90			7.39			12.04			20.11		
Amarillo	5.92			8.21			4.67			4.20			−2.54		

[1] Number of years averaged: At Garden City and Dalhart, 6; at Amarillo, 7.

Both milo and kafir have given higher average yields than corn at each of these stations. They have also been safer crops, having made crops of grain in some years when corn did not. They have also been more responsive to cultural operations, thus proving their better adaptation to conditions. On the sandy lands of this area corn makes a better showing in comparison with these crops than it does on the heavy, tight lands. On these latter soils corn has little place in this section. Where a comparison is made between milo and kafir it is seen that milo has produced more grain than kafir and that kafir has produced more roughage than milo. Kafir, however, has shown a somewhat greater response to methods that increase the yields, such as summer tillage. When equal values are assigned to the grain and to the roughage from each of the crops, the total return is generally about the same from each. At Garden City the grain crop alone has not been sufficient to pay for the cost of production. At Dalhart both crops have produced sufficient grain by all methods to pay a profit. At Amarillo milo has returned a profit from the grain alone by some methods. The crop of kafir grain at this station has not been sufficient from any method to pay the cost of producing the crop.

When a value, believed to be a conservative one, is assigned to the fodder, both crops show a profit from nearly all methods under trial at all the stations. The only two exceptions are milo following milo by spring plowing at Garden City and kafir by summer tillage at Amarillo. This latter has been on trial for only three years, all of which have been relatively unfavorable. At Garden City and at Amarillo the yields of both grain and fodder from both milo and kafir have been greater following small grain than following themselves on fall plowing. At Dalhart the reverse has been true except in the case of kafir forage.

Fall plowing has generally been a better preparation than spring plowing for both crops. At Amarillo the results with milo show little difference.

The yields following listing have not generally departed far in either direction from those on similar land spring plowed. The most marked departure is an increase in the yield of kafir as a result of listing at Dalhart.

Summer tillage as a preparation for these crops was not included in the experiments as originally outlined for Garden City. This defect has been remedied, but results of value have not yet been obtained. At Dalhart it has been the most productive and profitable method under trial. At Amarillo this method has been under trial for only three years. The results presented are not comparable with those from other methods. The data at hand indicate that marked increases in yields may be expected.

TILLAGE PRACTICES.

In the preceding pages data have been presented and discussed on each crop separately. The data and the experience gained and observations made during the investigations indicate that certain tillage practices are more or less general in their application. These will now be considered in their general application without reference to individual crops.

PLOWING AND ITS SUBSTITUTES.

In these investigations it has been assumed that the land should always be plowed for all crops following small-grain crops, except when it is ridged with a lister in the fall and cultivated down level in the spring without the use of the plow or when cultivated crops are planted with the lister. The practice of disking in small-grain crops on the stubble of the previous small-grain crop without plowing has not been tested sufficiently to warrant any definite recommendation at this time. This is a method that is sometimes resorted to in some parts of the Great Plains on account of its low cost, and it might be justified under certain circumstances. If this method were practiced it would undoubtedly be necessary to grow intertilled crops at frequent intervals in rotation with small grain to avoid damage from weeds, insects, and diseases, which would soon reduce crop yields.

WHEN DISKING MAY BE SUBSTITUTED FOR PLOWING.

These investigations have shown that when the corn crop has been grown on properly prepared land and kept free from weeds, the land does not require plowing in preparation for a following crop of small grain. Wheat, oats, and barley have usually given better yields on disked corn land than upon land that has been plowed. This, together with the fact that disking is cheaper than plowing, makes disking corn land generally the most profitable method of preparation for small grain. Disking potato land is probably as good a preparation for small grain as disking corn land and there are undoubtedly other intertilled crops, such as peas, beans, and peanuts, that will serve the same purpose. The sorghums, however, do not leave the ground in as favorable a condition for the crop that is to follow as the other crops mentioned.

USE OF THE LISTER IN THE FALL.

The practice of ridging with a lister as a substitute for fall plowing and cultivating down level without the use of a plow in the spring has been tested at most of the stations as a preparation for all of the small-grain crops considered in this bulletin except winter wheat. It has usually produced as good or better yields than fall plowing. Its lower cost has made it in many instances nearly or quite as profitable a method as disking corn stubble. In addition to its low cost it has the advantages of catching and holding the snow and checking soil blowing during the winter and of arresting run-off.

When the lister is used in preparing land for winter wheat, the listing is done immediately after the harvest of the preceding crop. The soil is worked down level, usually with a disk, in late summer or early fall, and then seeded with an ordinary grain drill. Very little differences in average yields between listing and plowing have been noted except at Hays, where the advantage is in favor of listing.

PLANTING WITH THE LISTER.

When the lister is used for planting corn, kafir, and milo, the land is left undisturbed from the time of harvesting the preceding crop until planting time the following spring, when the crop is planted with a lister. The ridges are then cultivated down level during the growth of the crop. At Judith Basin, Huntley, Belle Fourche, and

Dalhart, listing has produced markedly better yields than surface planting. At Scottsbluff, Hays, Garden City, and Amarillo there has been little difference. At Akron the advantage has been decidedly in favor of surface planting.

THE OBJECTS SOUGHT BY PLOWING.

The principal objects which are sought by plowing and the subsequent preparation of the soil are to prepare a suitable seed bed for the germination of the seed and the early growth of the seedling, to make the surface soil more receptive to water falling as rain or snow, and to prevent the growth of weeds. It is also important to have the surface of the soil in such condition that it will neither blow when exposed to high winds nor puddle when subjected to heavy beating rains. The latter considerations are of special importance when a period of several months intervenes between plowing and seeding, as in the case of summer tillage or of early fall plowing for spring-sown crops. The surface should then be left in a rough, cloddy, or ridged condition and a fine dust mulch avoided.

DEPTH OF PLOWING.

The data submitted and discussed in this bulletin show that subsoiling has failed to give the most profitable yields of either spring or winter wheat, oats, barley, or corn, at any of the stations where it has been tested. These results are in accord with those of other investigations with deep tillage that have been conducted by the Office of Dry-Land Agriculture. The evidence so far obtained from the investigations goes to show that nothing is gained by stirring the soil to a depth greater than is done by ordinary plowing 8 inches or less in depth.

HOW AND WHEN TO PLOW.

The comparative average yields from fall and from spring plowing at each station for corn, spring wheat, oats, barley, milo, and kafir have shown but small differences. As the land requires plowing for all annual crops except in those cases above noted, and as plowing is an expensive operation, it is a question of great economic importance as to how and when this plowing should be done. Much has been written upon this subject and many theories have been developed and advocated, but the investigations conducted in the Great Plains by the Office of Dry-Land Agriculture seem to show conclusively that no set rule can safely be followed. The best practice seems to be to do a good, clean-cut, workmanlike job of plowing to a depth of 4 to 8 inches when the soil is in proper condition and the work can be done to the best advantage, taking into consideration the most economical distribution of labor throughout the year.

ACCESSORY TILLAGE.

Under the heading of accessory tillage may be included three distinct practices: (1) Summer tillage, or the tillage of an uncropped fallow field during an entire season; (2) shallow tillage after the crop is removed at harvest and before seeding in the following spring; and (3) the cultivation of an intertilled crop, like corn or potatoes, during the earlier part of the growing season. Each of the three practices above mentioned can again be subdivided into two groups, namely, tillage for the destruction of weeds and tillage for improving the physical condition of the soil.

DESTRUCTION OF WEEDS.

The destruction of weeds is nearly always desirable, as under dry-farming conditions weeds are one of the most serious obstacles to successful crop production. When summer tillage is practiced on a bare fallow during the entire season, cultivation should be frequent and thorough enough to destroy all weeds before they attain sufficient size to transpire appreciable quantities of water or to reseed themselves. This tillage will also keep the surface in a condition sufficiently loose and open to allow the rain that falls to penetrate it. When the soil becomes well filled with water early in the season and additional rains can reasonably be expected, it may sometimes be desirable to allow the weeds to attain a larger growth and then plow them under in order to provide additional organic matter in the soil, but it must be borne in mind that this gain in organic matter is made at the expense of the soil moisture.

Tables II to VII show that summer tillage is, with the exception of green manuring, the most expensive and least profitable method under trial. Exceptions are to be noted in the case of kafir and milo at Dalhart, corn at Scottsbluff, and winter wheat at North Platte and Huntley.

The purpose of summer tillage is accomplished by the prevention of vegetative growth rather than by the maintenance of a mulch. Numerous experiments made in connection with this work have furnished an abundance of evidence that when vegetative growth is restrained the loss of water from a mulched surface is practically the same as from an unmulched one.

The cheapest and most efficient methods of weed destruction necessarily form a soil mulch. The results accruing from the prevention of weed growth have been very generally attributed to the mulch itself when the mulch is, in fact, only incidental.

Tillage for the purpose of destroying weeds after harvest is warranted only in those exceptional cases when sufficient water remains in the soil to start weed growth after harvest or when heavy rains come soon after. In such cases early fall plowing is the most effective method of destroying the weeds and thus saving the moisture that would be used by them if allowed to grow. The same object may be accomplished by disking soon after the weeds have started. This method has the advantage of being more rapid than plowing, thus making it possible to cover more ground with the same number of teams and men. But as the land will have to be plowed before another crop is sown, the labor of disking is mostly lost, although the labor of plowing the disked land may be somewhat less than if it were not disked and a better job of plowing may sometimes be done on the disked land. The cost of early fall plowing or disking, when the weather is hot and the men and teams are needed for stacking, thrashing, and hauling grain, is greater than later in the fall, when the weather is cooler and there is less other work for men and teams. All of these facts should be taken into consideration before going to the extra expense of tillage to kill weeds immediately after harvest.

Spring plowing or disking, as soon as the weed seeds have germinated, is usually a profitable practice. Where small grain is to be sown, the sowing should be done soon after plowing; but where corn, potatoes, or the sorghums are to be grown there is often a period of several weeks between the time of the germination of the weed seeds and the time when the season is sufficiently advanced to plant the crop. This period should be utilized as far as possible for the destruction of weeds before the crop is planted. Much labor in keeping the crop free from weeds during its growing period can thus be saved.

Harrowing small grain for the destruction of weeds after the grain is sown and until it has reached a height of 3 or 4 inches may sometimes be practiced to advantage. Experimental evidence does not show it to be generally profitable. Harrowing corn and potatoes after planting and until the young plants have attained a height of 2 or 3 inches is quite generally practiced to advantage.

It is absolutely essential for the most profitable growth of corn, potatoes, the sorghums, and, in fact, all the intertilled crops, that sufficient tillage be given to keep the growing crop free from weeds until the plants have attained such growth that they will be seriously injured by the cultivators or the horses.

IMPROVING THE PHYSICAL CONDITION OF THE SOIL.

As has been already shown, accessory tillage for the destruction of weeds usually will accomplish all that can be accomplished by tillage in keeping the soil in proper physical condition during the intervals between plowings. There is, however, one exception, namely, the accessory tillage immediately preceding the seeding of the crop for the purpose of preparing a suitable seed bed. The small-grain crops require a mellow surface and a firm condition of the soil below. In order to bring about this condition it is generally necessary to resort to either harrowing or disking, or both. The deeper the plowing, the more thorough should this preparation be.

In the planting of corn, potatoes, and most other intertilled crops generally grown in the dry-farming regions, this accessory tillage between plowing and planting is not so essential. These crops do not require as firm a seed bed as the small grains, and there is also a better opportunity for such tillage immediately after the crop has been planted. Moreover, it has been found that when the plowing has been properly done, better germination and growth are generally secured where there is little or no stirring of the soil between plowing and planting except such as is necessary for the destruction of weeds.

REGIONAL ADAPTATION OF CROPS.

Spring wheat is adapted to the northern portion of the Great Plains. Its growth in North Dakota and Montana has been quite generally profitable in all years when seasonal conditions permitted the profitable production of any crop. Spring wheat is adapted, though in a somewhat lesser degree, to conditions in western South Dakota, western Nebraska, and eastern Colorado. It has not shown itself to be adapted to conditions in western Kansas, Oklahoma, Texas, and northeastern New Mexico.

Winter wheat will tend to replace spring wheat where it can be successfully grown. It has proved to be adapted to conditions in Montana, some parts of South Dakota, Nebraska, Colorado, and the major portion of Kansas. In southwestern Kansas and northwestern Texas it has not been profitably produced. It has given higher yields than spring wheat at Huntley, Belle Fourche, Scottsbluff, North Platte, Akron, and Hays.

Oats are better adapted to conditions existing in Montana and North Dakota than to those of any other sections of the Plains included in these investigations. They have been profitably grown by some method at Belle Fourche, Scottsbluff, North Platte, Akron, Hays, and Amarillo, but they have shown markedly less adaptation to the conditions at these stations than to those farther north. They are not at all adapted to conditions such as have existed at Garden City and Dalhart.

Barley, like spring wheat and oats, is better adapted to the northern than to the southern portion of the Plains. At North Platte and Akron it is less adapted but has been profitably produced. At Belle Fourche and Scottsbluff its growth is a questionable practice. In most of western Kansas and northwestern Texas its growth should be discouraged.

Corn has been grown at all the field stations in the Plains area. At only five stations, Huntley, Dickinson, Scottsbluff, North Platte, and Akron, has it shown possibilities for profitable production as a cash grain crop. As a feed crop, which includes the utilization of both roughage and grain, it can be profitably grown in all sections north of the southern line of Nebraska and in eastern Colorado. In the northern portions of western Kansas it will compete with the sorghums as a feed crop. South of central Kanass some of the sorghum crops have been more profitable than corn.

Milo and kafir for both grain and feed are well adapted to conditions in western Kansas, western Texas, Oklahoma, and eastern New Mexico.

CONCLUSIONS.

These investigations furnish strong presumptive evidence upon which to base the following conclusions:

(1) When the climatic conditions are as favorable as those often experienced in all parts of the Great Plains area on all the types of soil represented at the 14 stations, profitable crops can be produced by any one of several different cultural methods such as are in common use.

(2) When the climatic conditions are as unfavorable as those often experienced in all parts of the Great Plains area on any of the types of soil represented, no profitable crop of any kind so far tested can be produced by any of the cultural methods that have been under investigation.

(3) Under the normal conditions prevailing in any part of the Great Plains for a term of 10 years on any type of soil represented at any of the stations, some crops can be produced at a profit when proper cultural methods are practiced, provided that the prices of labor and of farm produce bear the same relation to each other as those which have prevailed there during the last 10 years.

(4) No single crop tested in these investigations can be raised profitably in all parts of the Great Plains area on any type of soil by any cultural method so far tested.

(5) As forage crops of some kind can profitably be grown at all stations, they must occupy an important place in any system of farming adapted to the Great Plains. Sufficient live stock must be kept to convert these crops into finished products on the farm, and sufficient forage must be produced and stored during favorable seasons to carry the live stock through specially unfavorable seasons.

(6) Good farming is as essential to success in the Great Plains area as elsewhere. Good farming means practicing the best methods of producing the largest crops at the lowest relative cost of production and leaving the soil in the best condition for the production of subsequent crops. Good farming may involve methods either intensive or extensive, either expensive or inexpensive; and it must be practical and economical as well as scientific and thorough in order to be good farming. It is just as poor farming to go to too much expense as it

is to go to too little expense to accomplish a given result. These investigations show that the largest net profits have usually been obtained from crops raised by cultural methods involving a low cost of production rather than from high yields obtained under methods involving a high cost of production. Lessening the cost of production without proportionally lessening yields should therefore be given first consideration. In other words, extensive rather than intensive systems of farming should be followed.

(7) Different types of soil and different combinations of climatic conditions require different cultural methods and different combinations of crops to produce the most profitable results.

(8) The personality of the farmer and his family; the size, location, soil, and environment of the farm; market facilities and prices; the available capital, in cash, labor, or equipment, may any or all be determining factors in the problem of profitable dry farming in the Great Plains area.

(9) Dry farming in the Great Plains area, in common with all farming, to be successful must be systematized, and in order to accomplish this, some definite rotation of crops should be established. In planning such a rotation, due consideration should be given to all the factors here enumerated, as they apply to each particular farm and farmer. With these considerations clearly in mind, it is believed that no intelligent farmer will experience any great difficulty in adopting a system of crop rotation and farm organization that will be better adapted to his conditions than any that could be proposed by anyone less familiar with these conditions than is the farmer himself.

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